The GCSS Lagrangian Intercomparisons

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Thanks: Irina Sandu (ECMWF), Stephan de Roode (TU Delft)
Peter Blossey (UW), other participating modelers

Outline

1. Background and goals
2. Idealized composite Sc-Cu transition case
3. ASTEX Lagrangian 1 case study

Focus on case setup and LES results

Background and goals

- Since 1993, GCSS boundary layer cloud working group (BLCWG) has had frequent LES/SCM intercomparisons of marine boundary layer cloud dynamics/microphysics in Sc, Cu, and transitional regimes.
- Parameterizations have greatly improved, but Sc-Cu transition remains key global/regional modeling problem.
- Two prior BLCWG studies oriented at Sc-Cu transition:
  - 1995: ASTEX Lagrangian 1 (NE Atlantic)
  - 2003+: GCSS Pacific Cross-Section Intercomparison (NE Pacific; global/regional models)
- In late 2008, BLCWG decided to revisit the subtropical Sc-Cu transition with new generation of LES/SCMs.
- European EUCLIPSE project funded in 2009 to help lead these intercomparisons. First meeting Sept. 2010.

Two complementary intercomparisons

- Composite summer NE Pacific case (Sandu et al. 2010 ACP) based on modern satellite observations of cloud evolution following thousands of reanalysis-based boundary-layer air column trajectories. Leader: Sandu
  - averages over ‘quirks’ of individual cases
  - no direct observations of vertical thermodynamic structure.
  - Is composite case meaningful to compare with obs?
- Revisit ASTEX Lagrangian 1 case (obs: Bretherton and Pincus 1995; SCM/LES: Bretherton et al. 1999; Duynkerke et al. 1999) with new models. Leader: DeRoode
  - 48hr of Lagrangian multiaircraft observations
  - Strongly forced: dSST/dt up to 6K/day

Composite Sc-Cu transition case

Here, we'll focus on the LES results only. Several SCM groups have also submitted results.

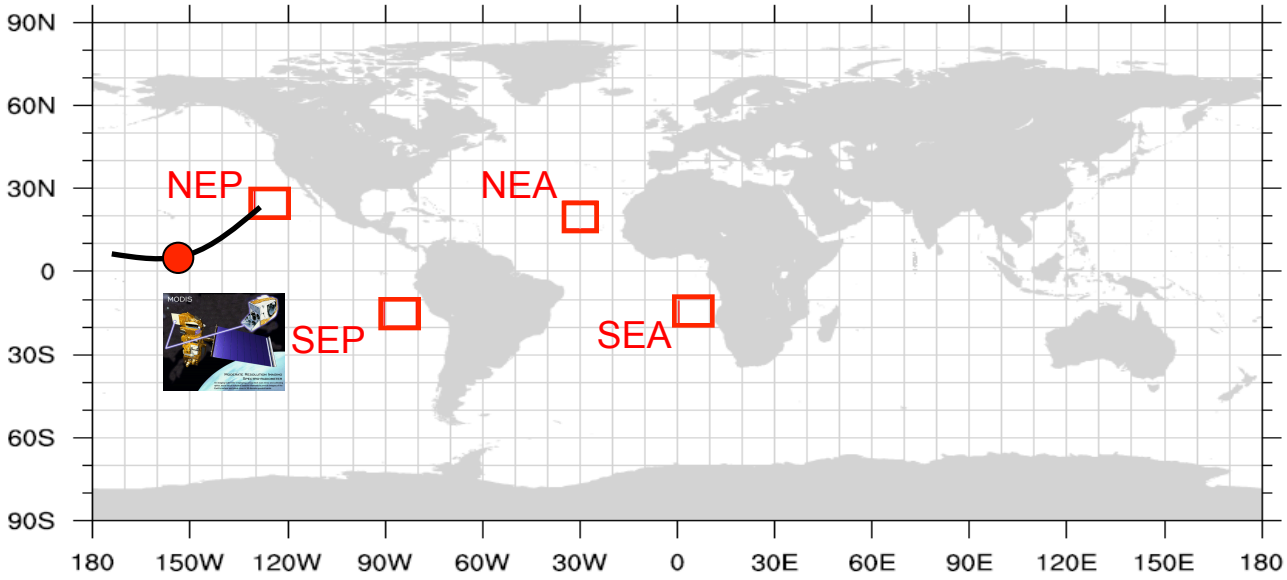
Lagrangian analysis of the air mass flow

How? Trajectories + Re-analysis + Satellite data

HYSPLIT (ERA-INTERIM) | ERA-INTERIM | MODIS (Terra, Aqua) AMSR-E

When? 2002-2007 (May to October in NE, July to December SE)
Starting time: 11 LT, Duration: 6 days, Height: 200m

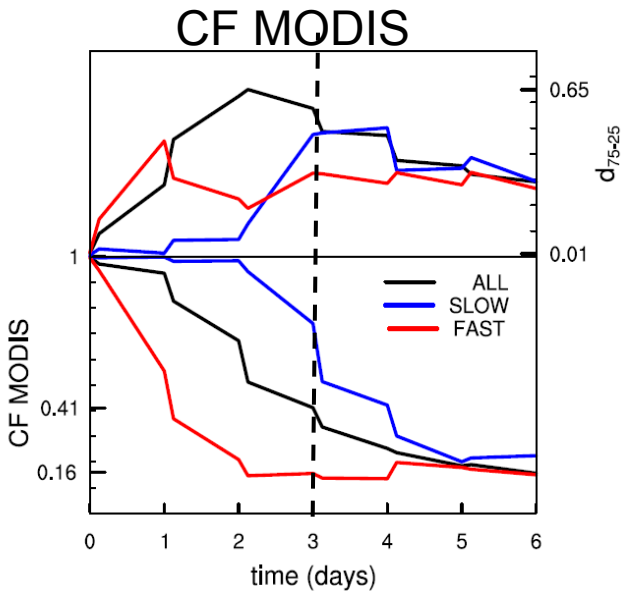
Where? Klein&Hartmann (1993) zones : NE/SE Atlantic, NE/SE Pacific



Sandu, Stevens and Pincus, ACP, 2010

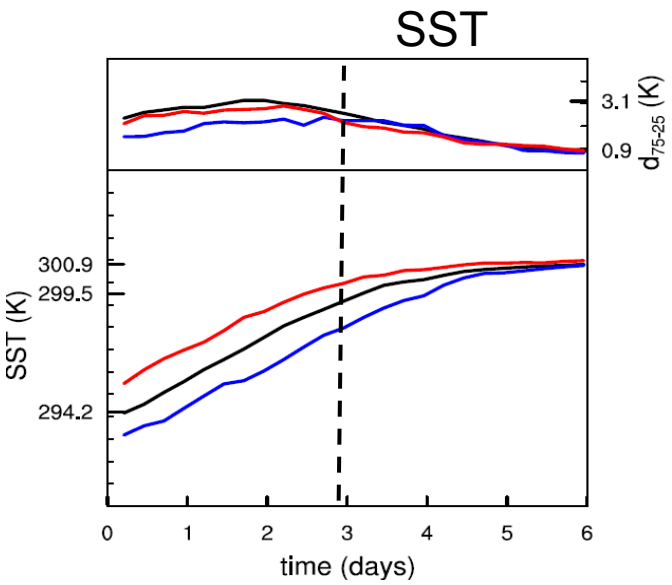
An ensemble of composite cases: slow, intermediate and fast transitions

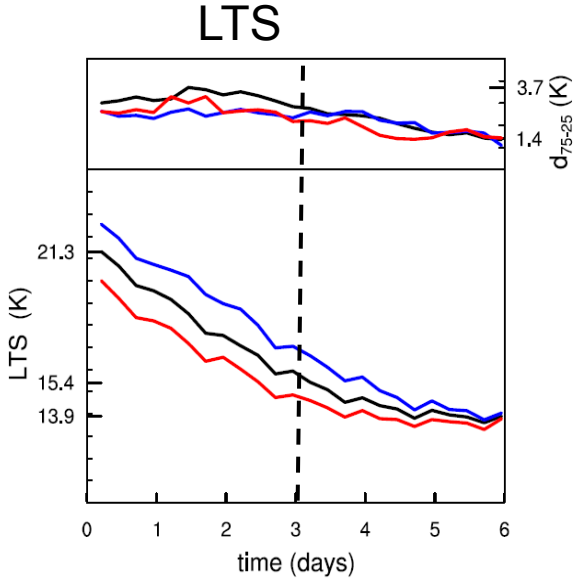
Composites NEP
JJA 2006-2007

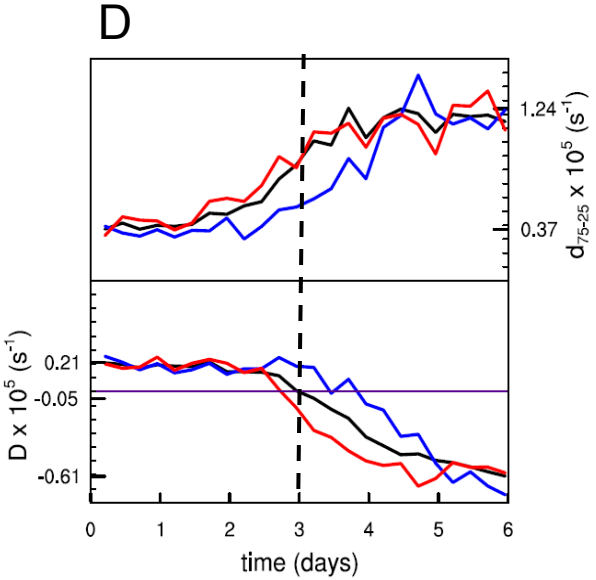


ref
slow
fast

3 days







Our questions

Are the LES able to reproduce:

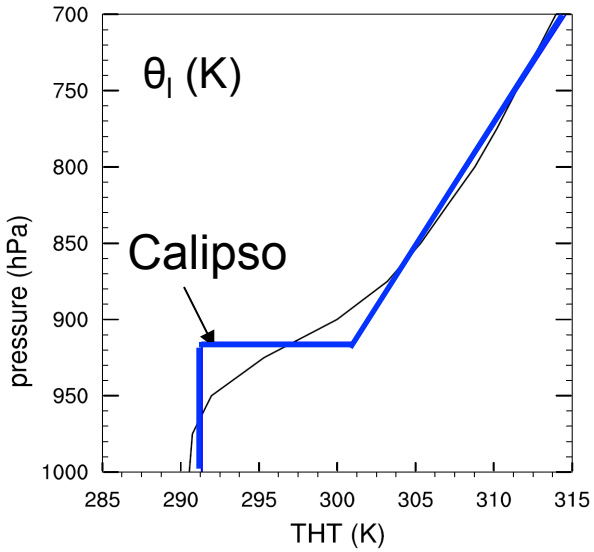
- ✓ the observed changes in cloudiness induced by changes in the SST/LTS?
- ✓ the transition's pace and its dependence on the inversion strength?

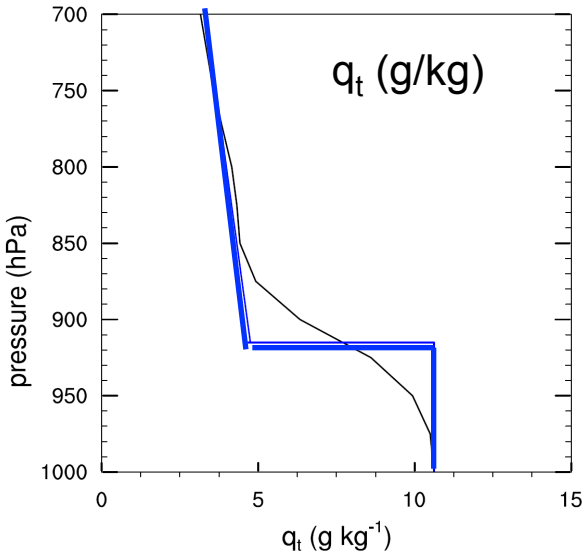
Do they agree in term of :

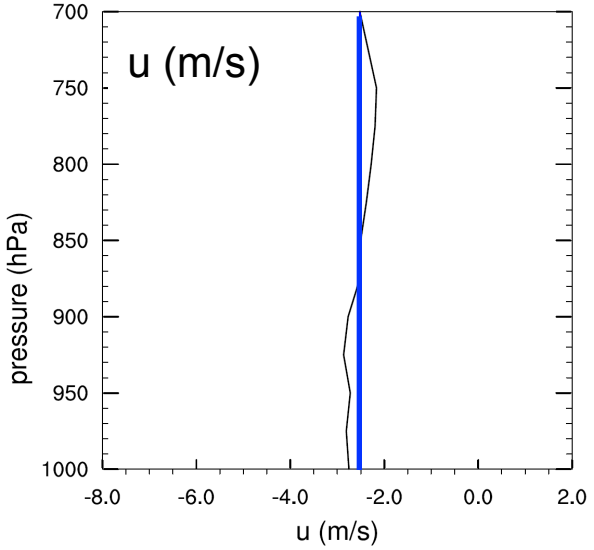
- ✓ The decrease in cloud albedo and cloud cover during the 3 days
- ✓ The time evolution of the cloud fraction
- ✓ The growth rate of the boundary layer

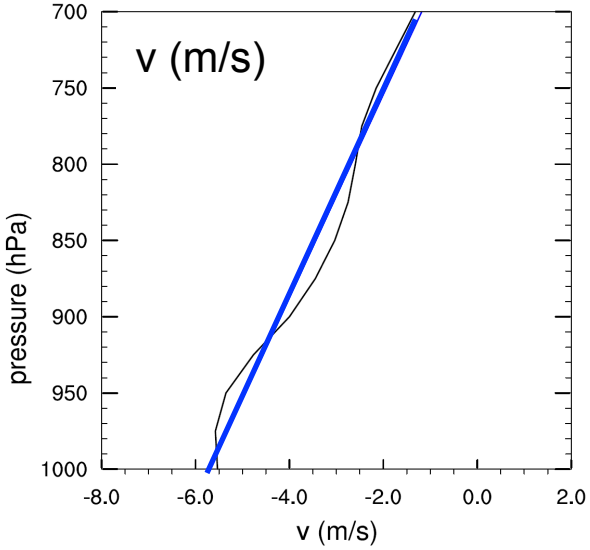
Composite REF case : NEP - JJA 2006-2007

Initial profiles (10 LT)

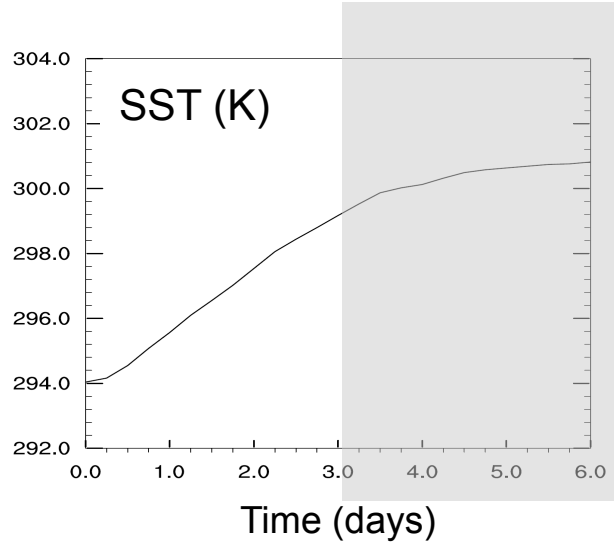


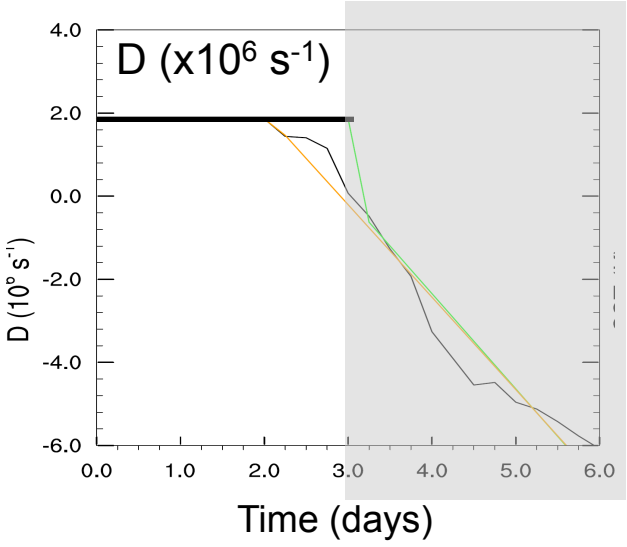




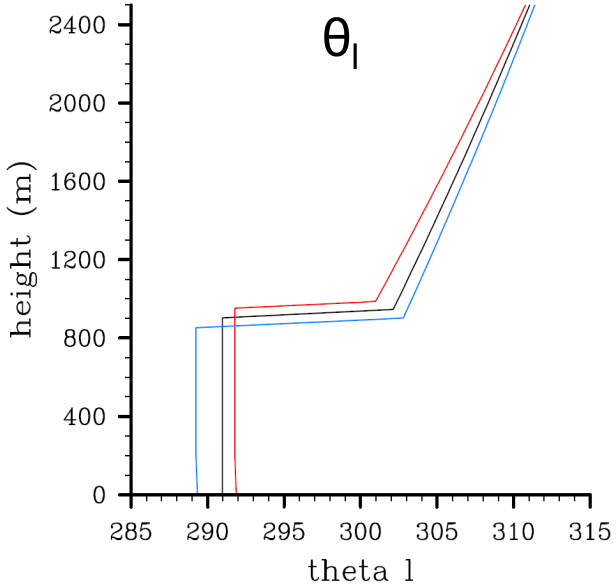


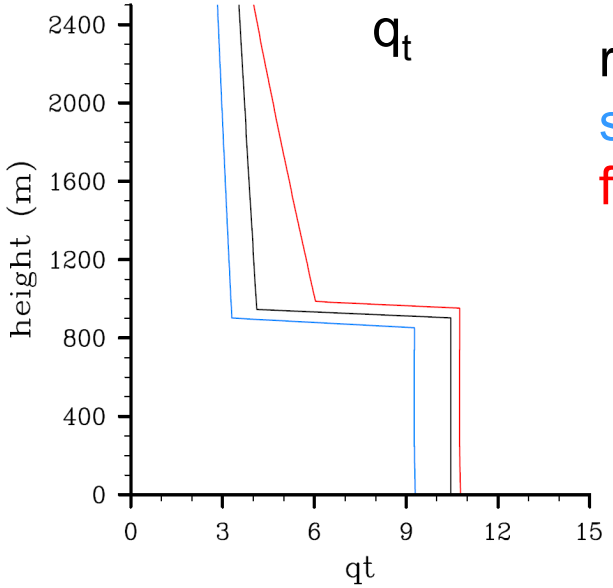
Forcing



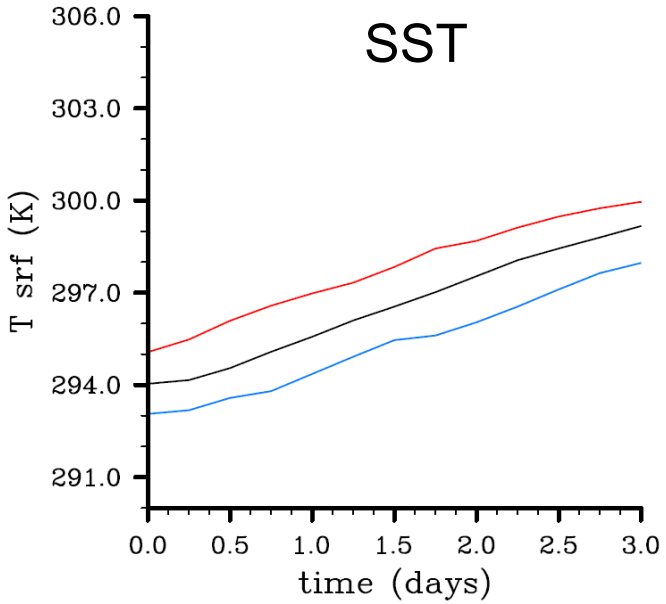


Initial conditions





ref
slow
fast



Divergence same as REF
No advective tendency

…from now on,
we focus on the
reference case

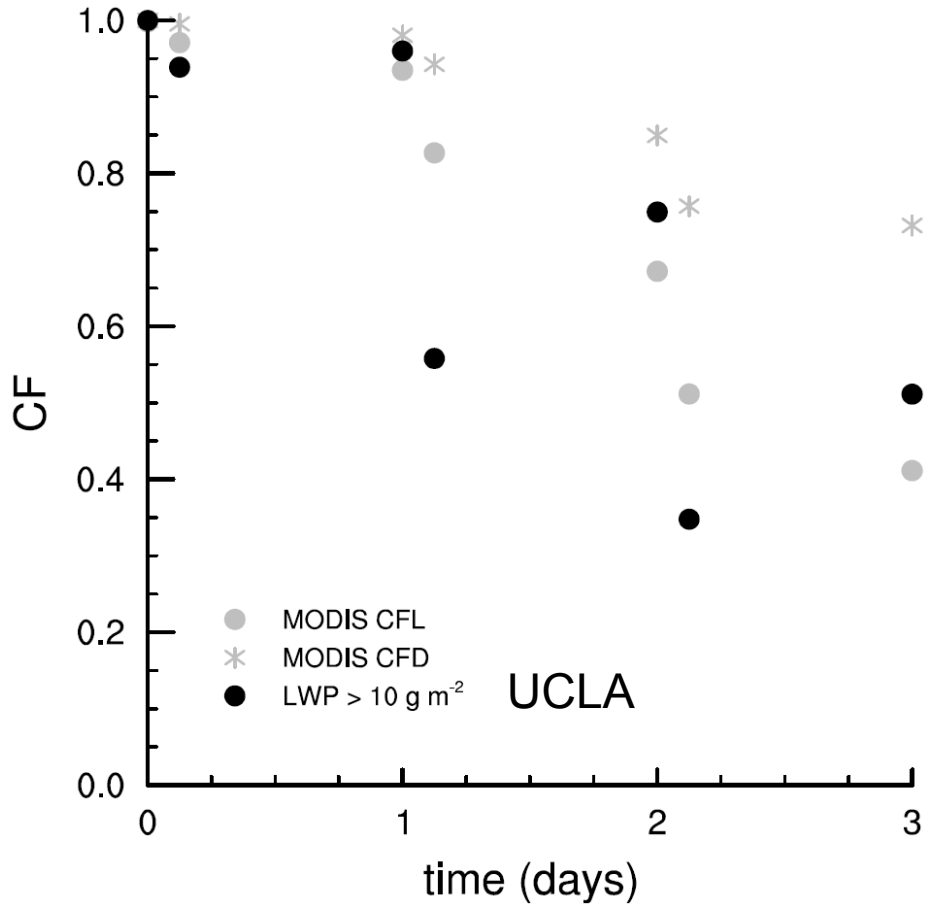
Simulations

- ✓ initial time : 10 LT, duration: 72 hours
- ✓ initial date: 15 July (but 15 June for UCLA)
- ✓ diurnal cycle of solar radiative forcing taken into account
- ✓ cloud droplet number concentration: 100 cm^{-3}
- ✓ resolution : x = 35m, z = 5m (at cloud top)
- ✓ domain size : 4.48 X 4.48 X 3.2 km (128 x 128 X 428 points)

Models & participants

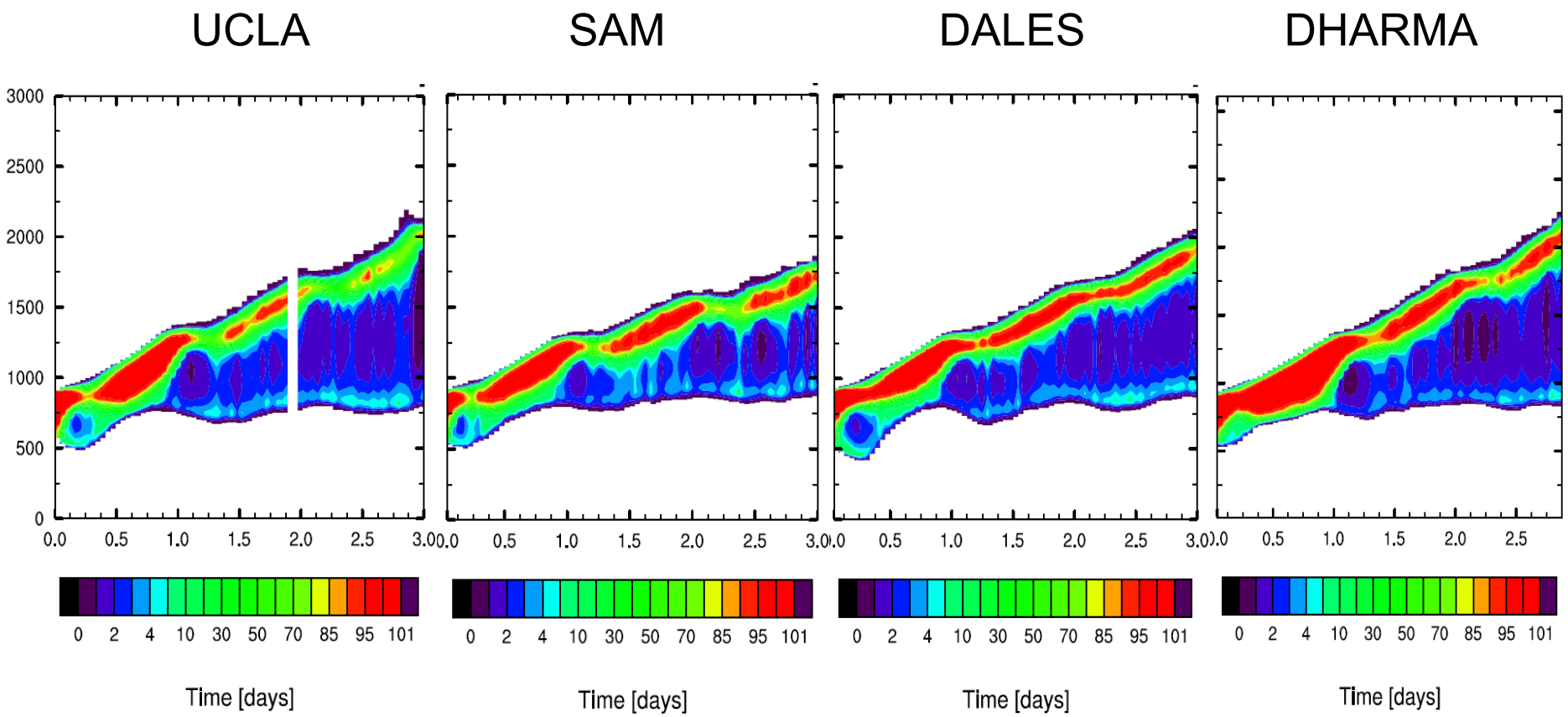
	REF	FAST	SLOW
✓ UCLA-LES (Irina Sandu)	✓	✓	✓
✓ DALES (Johan van der Dussen, Stephan de Roode)	✓	✗	✗
✓ UKMO (Adrian Lock)	✓	✓	✓
✓ SAM (Peter Blossey, Chris Bretherton)	✓	✗	✗
✓ DHARMA (Andy Ackerman)	✓	✗	✗

Comparison with 1000/1300 MODIS cloud cover



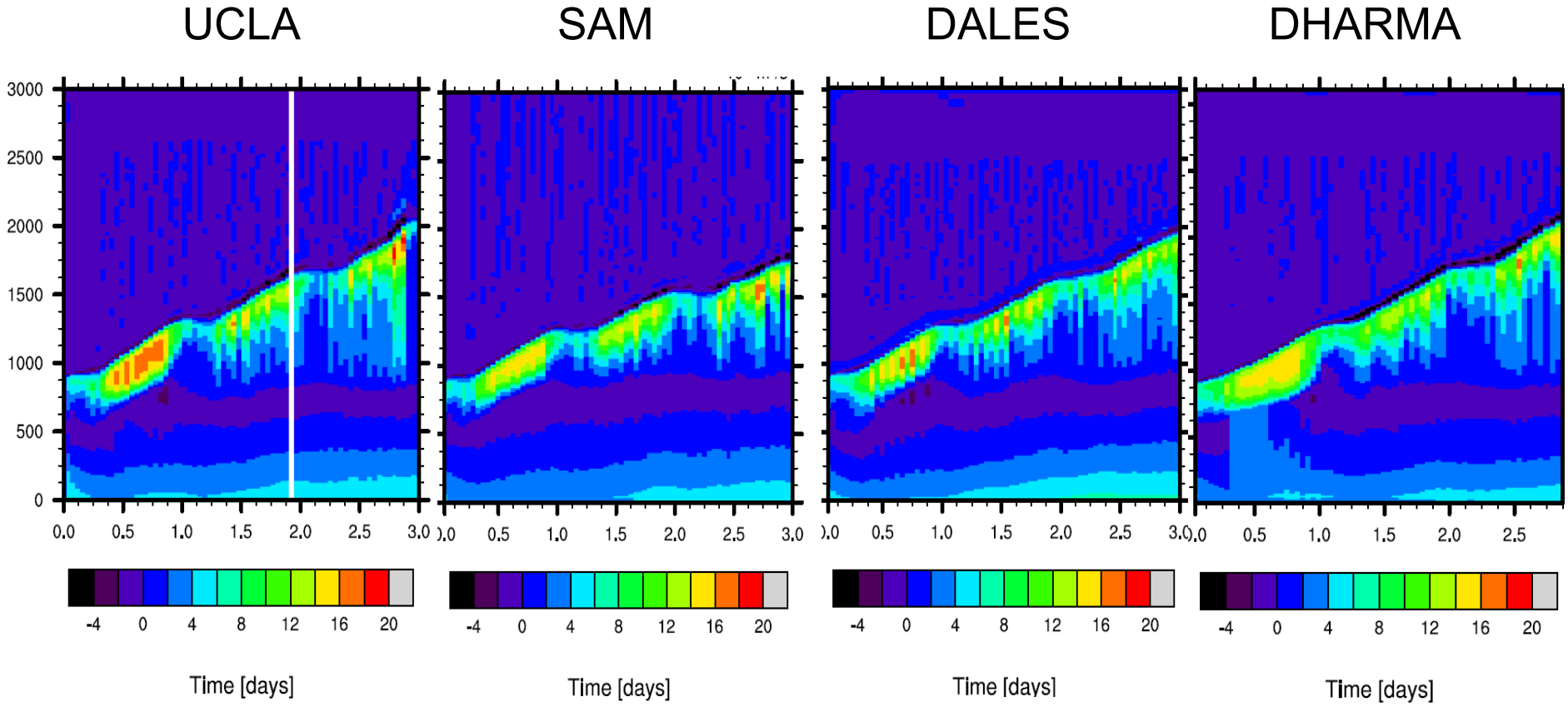
(simulated diurnal cycle maybe too strong?)

LES results: Cloud fraction

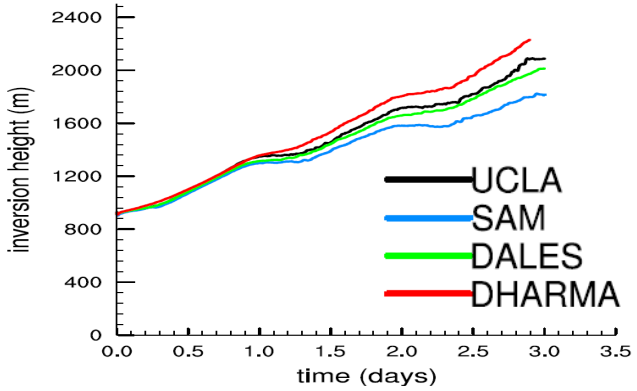


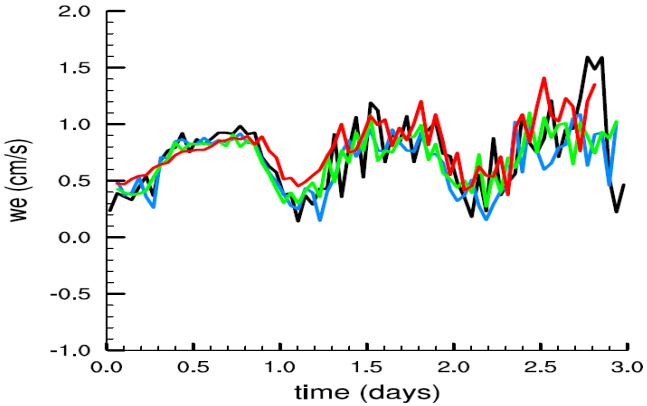
- Overall, there is encouraging agreement between the LES models
- We'll now see this holds for other fields too.
- There are still a few small configuration differences and bugs.
- Full SAM outputs are available for CPT use from Peter Blossey.

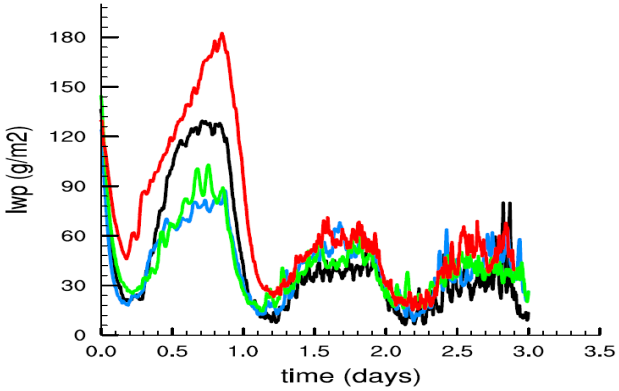
$w'\theta_v'$ (10^{-4} m^2/s^3)

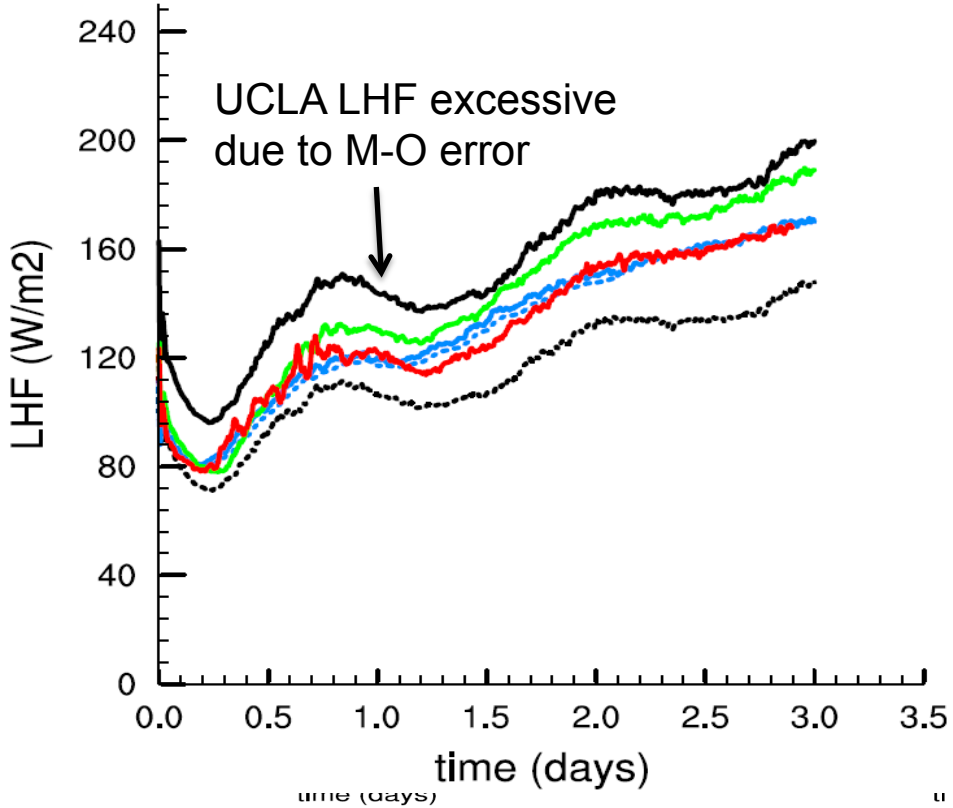


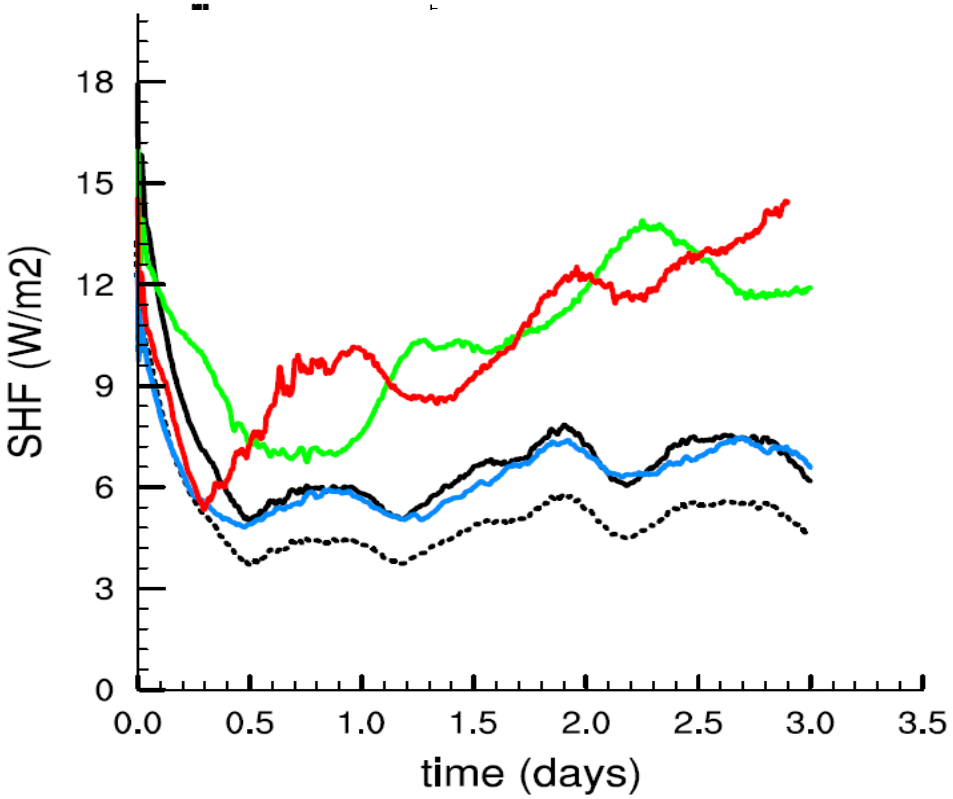
LES time series



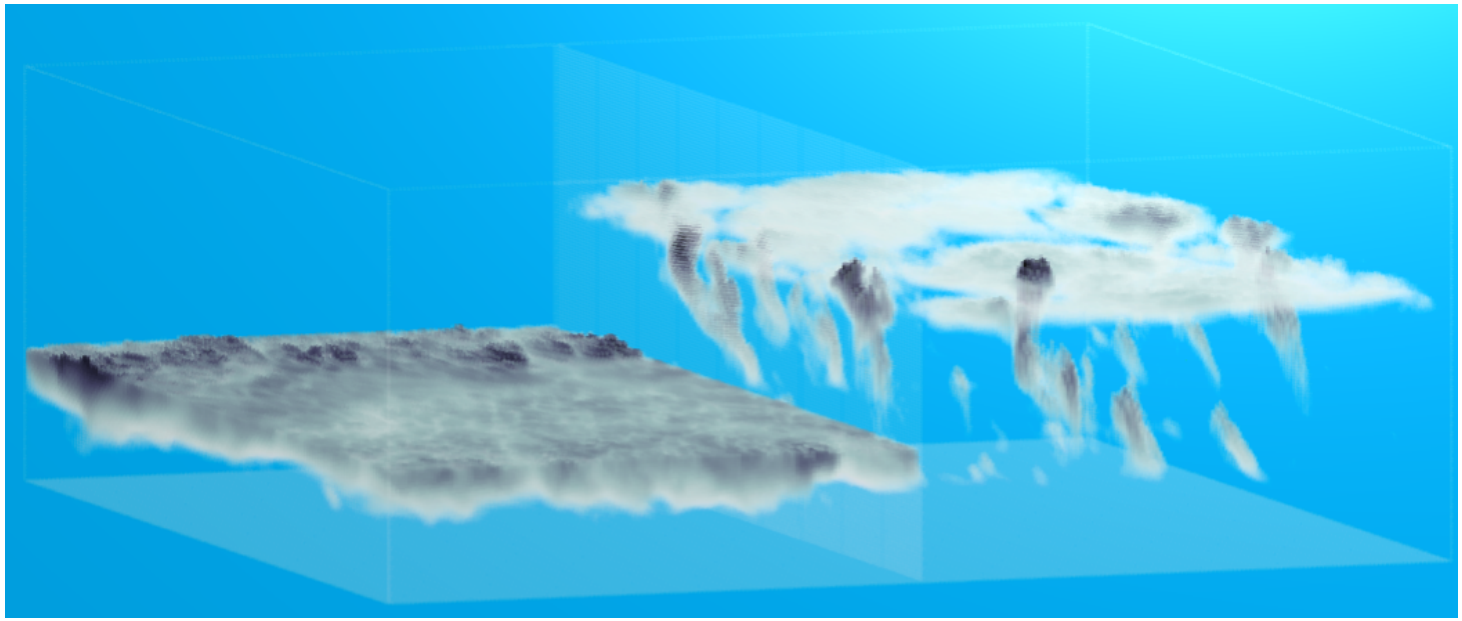








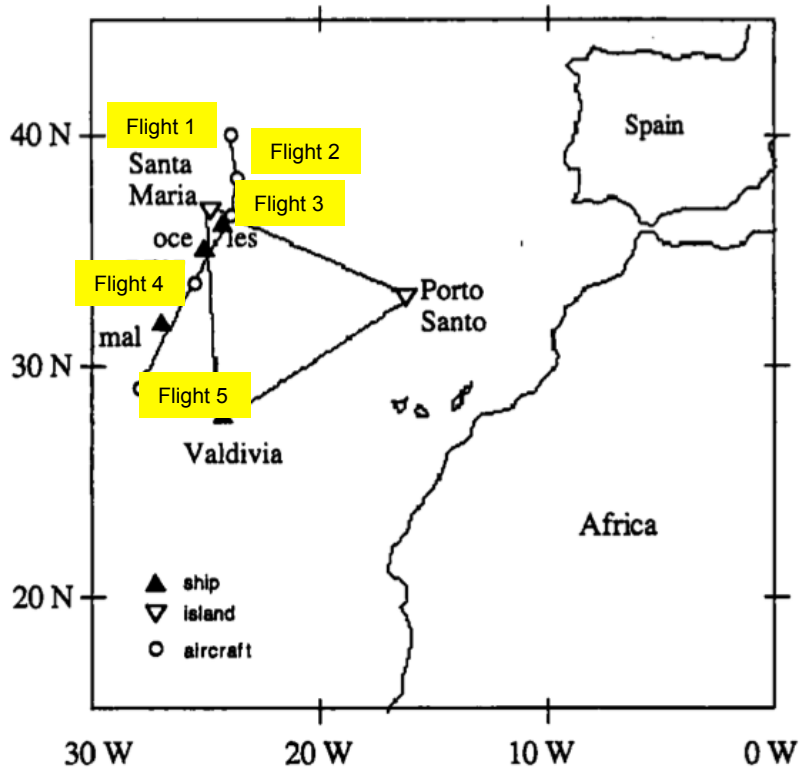
The ASTEX Lagrangian model intercomparison case



Stephan de Roode and Johan van der Dussen

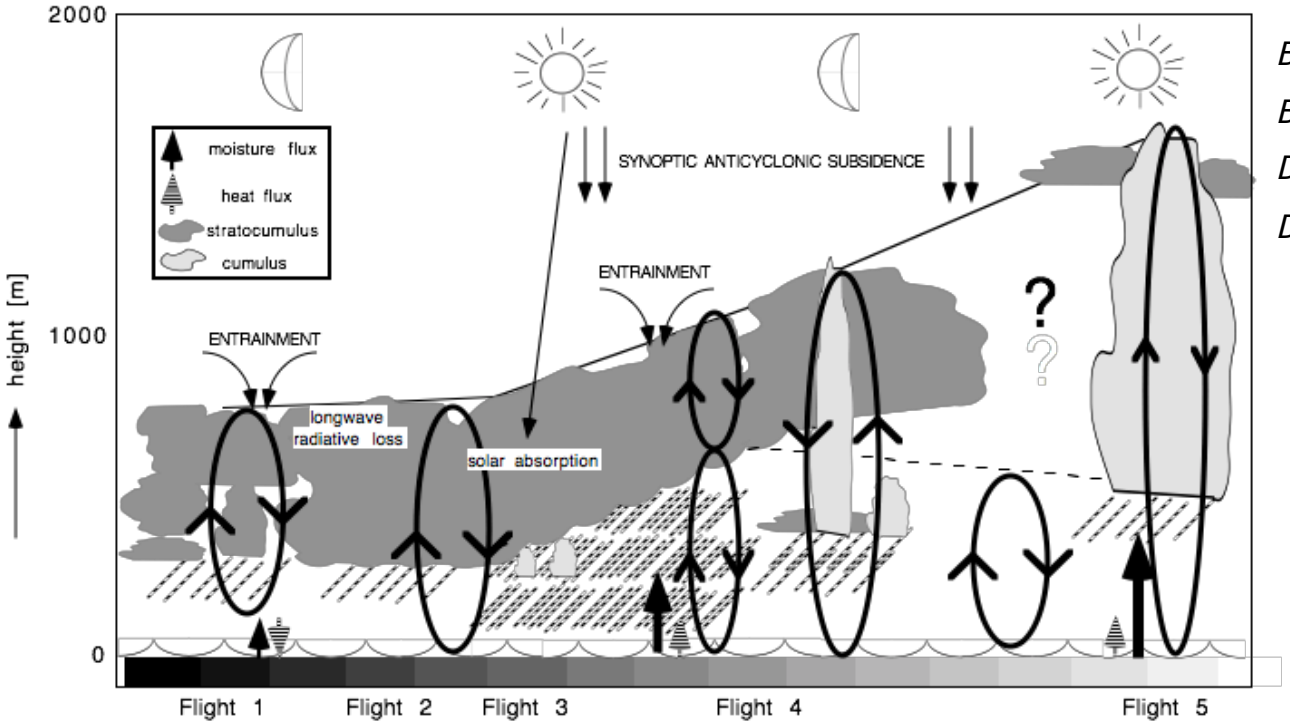
TU Delft, Netherlands

The ASTEX First Lagrangian (June 1992)



- Lagrangian evolution of cloudy boundary layer observed
- Five aircraft flights
- Duration: two days

ASTEX observed stratocumulus to cumulus transition



Bretherton and Pincus, 1995

Bretherton et al, 1995

Duynkerke et al, 1995

De Roode and Duynkerke, 1997

GCSS case, 1995

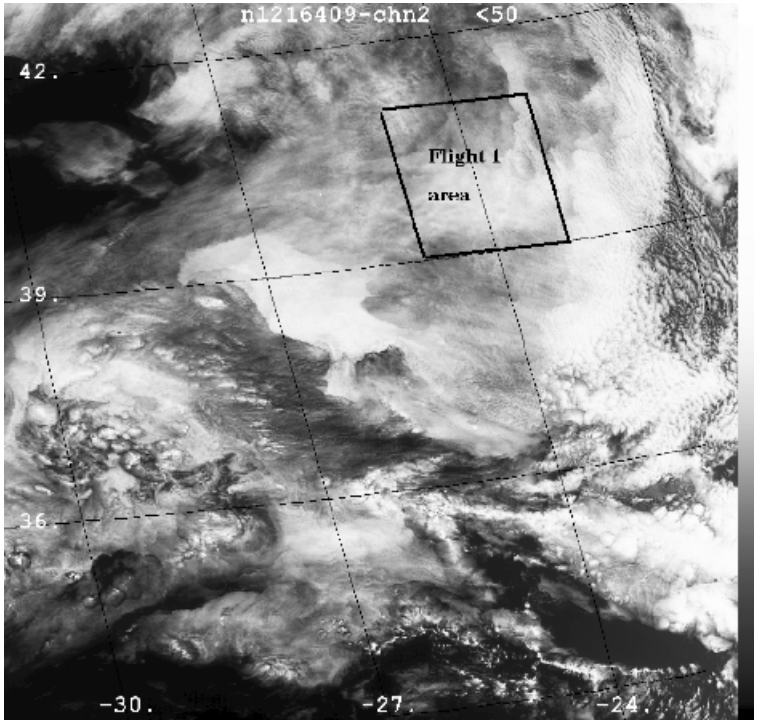
EUCREM/GCSS, Duynkerke et al, 1999

like GCSS ATEX case, Stevens et al, 2001

Study of ASTEX First Lagrangian wtih SCM and 2D models by Bretherton et al, 1999*:*

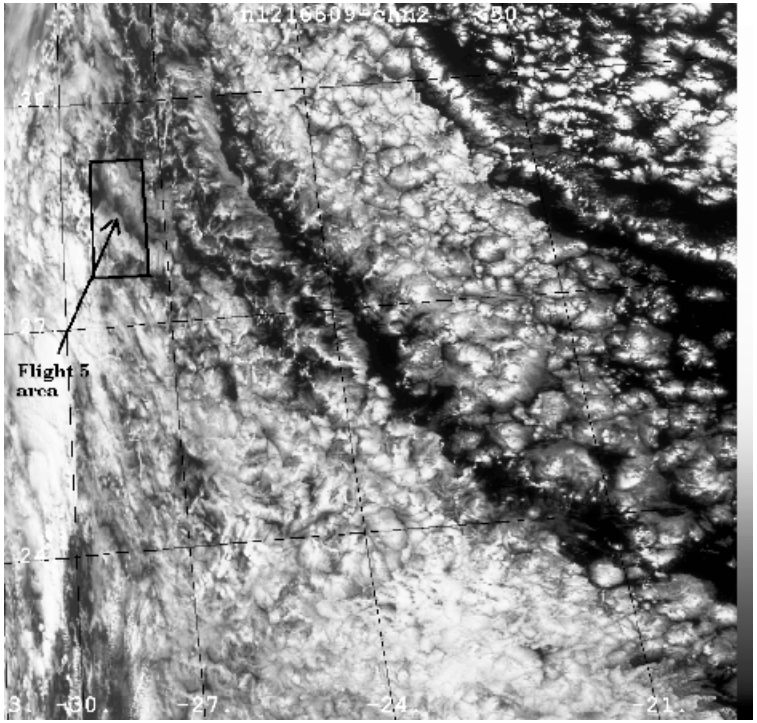
"there are substantial quantitative differences in the cloud cover and liquid water path between models."

Satellite images Flights 1 and 5



latitude

longitude

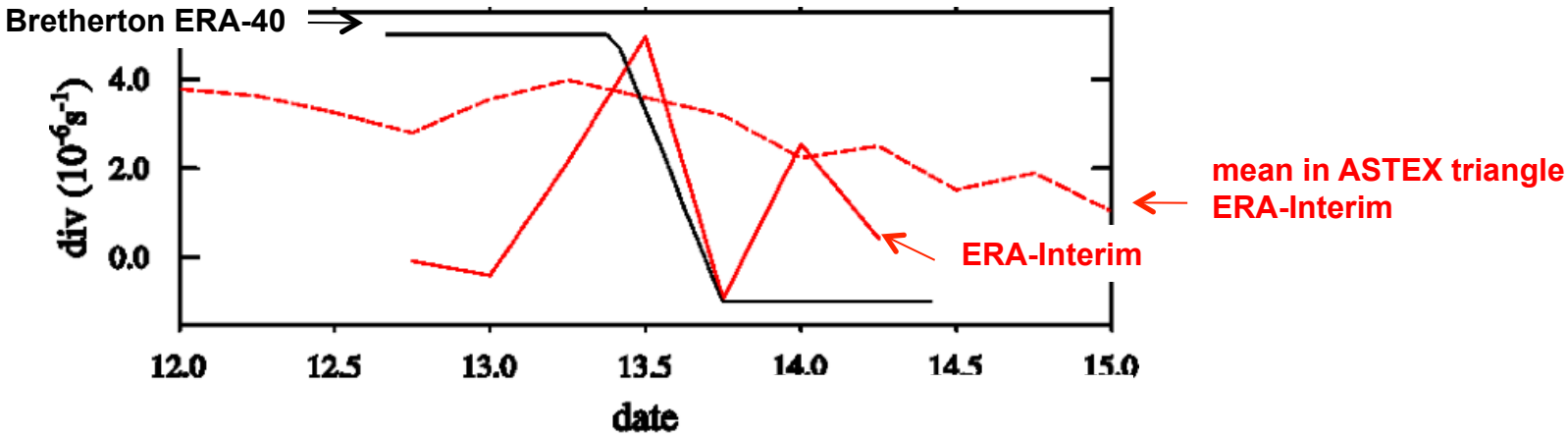


precise position air mass during last flight uncertain

Model initialization

Model set up and large-scale forcing

- Large-scale forcing (SST & subsidence) from Bretherton et al. (1995, 1999); subsidence still uncertain.
- Model initialization from Flight 2 (A209)
  - Identical to first GCSS ASTEX "A209" modeling intercomparison case
- Microphysics: drizzle and cloud droplet sedimentation
- Shortwave and longwave radiation



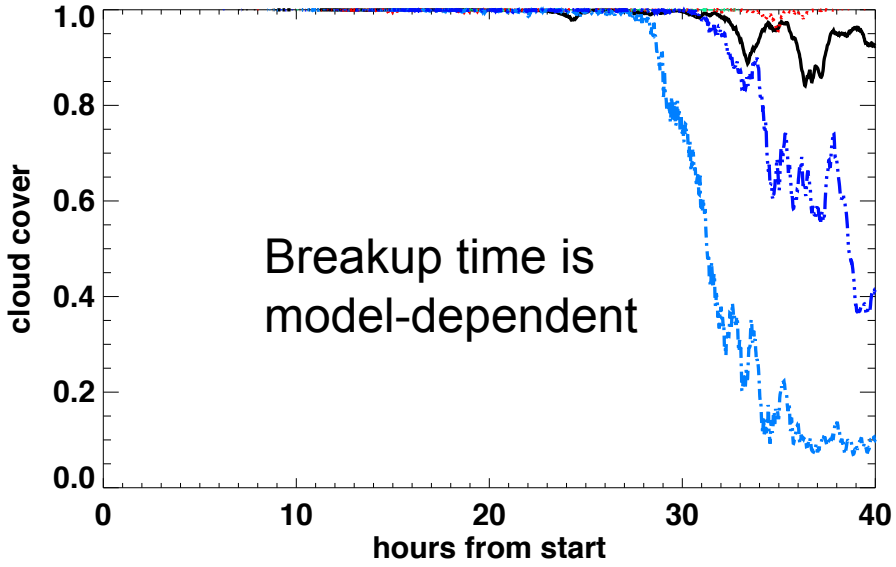
LES participants

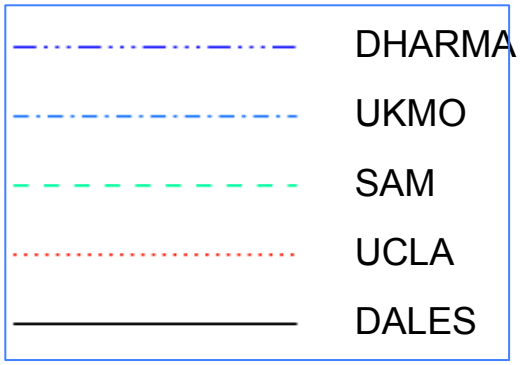
LES model	Institution	Investigator
DALES	TU Delft	de Roode
UCLA/MPI	MPI	Sandu
UKMO	UKMO	Lock
SAM	Univ Washington	Blossey
DHARMA	NASA	Ackerman
Warschau	Warschau	Kurowski

Use SCM version identical to operational GCM

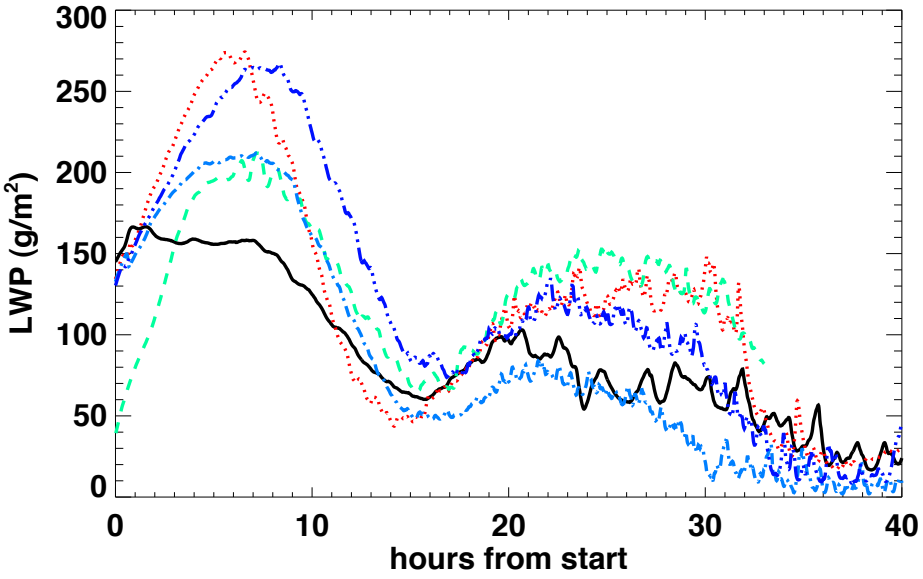
SCM model	Institution	Investigator
RACMO	KNMI	dal Gesso
EC-Earth	KNMI	dal Gesso
ECMWF	ECMWF	Sandu
ECMWF-MF	DWD	Koehler
JMA	Japan	Kawai
PDF based scheme	Wisconsin	Larson
LMD GCM	LMD	Bony
UKMO	UKMO	Lock
Arpege	Meteo France	Bazile/Beau
MPI	ECHAM	Suvarchal

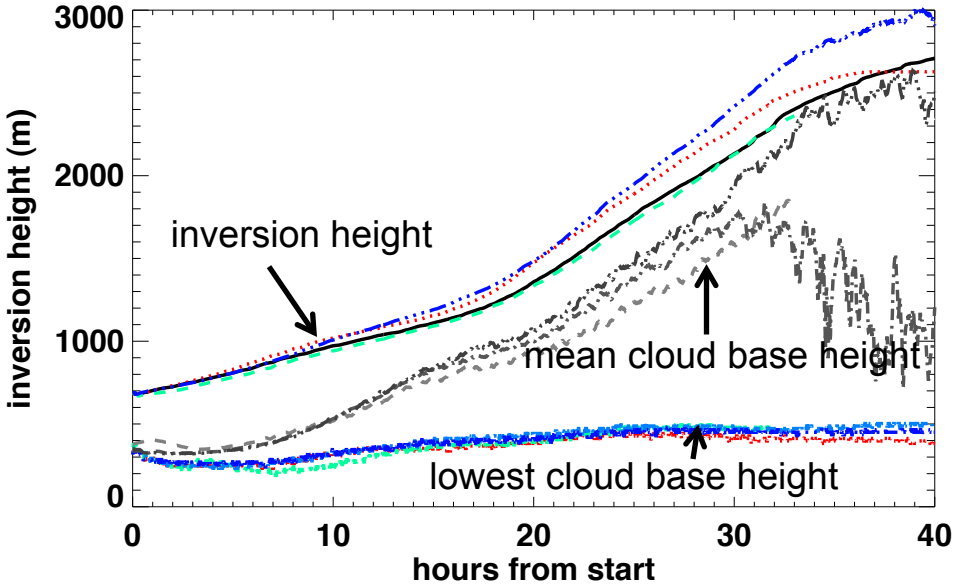
LES results





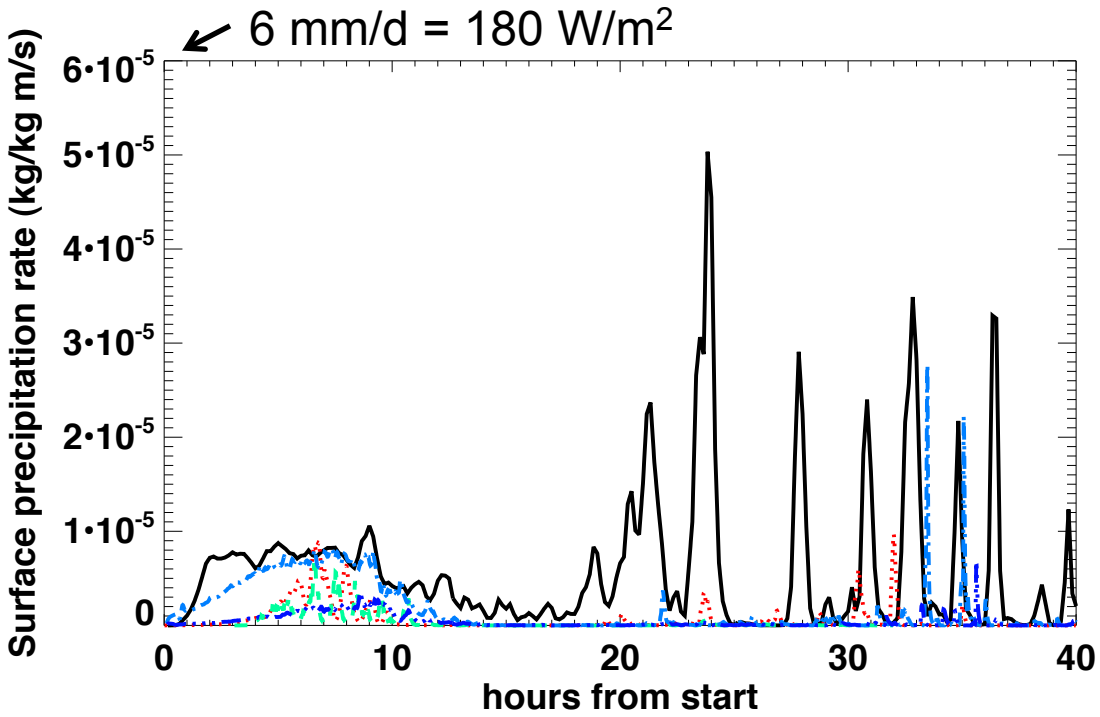
DALES: large domain shown

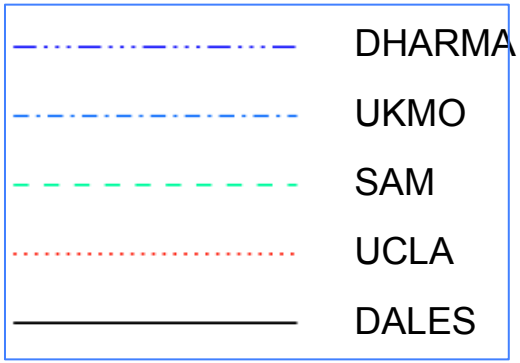




- Boundary layer drifts too deep compared to observations after 20 hours (less subsidence?)
- Last 10 hours of simulations are less reliable (sponge layer, coarser vertical resolution)

Surface precipitation

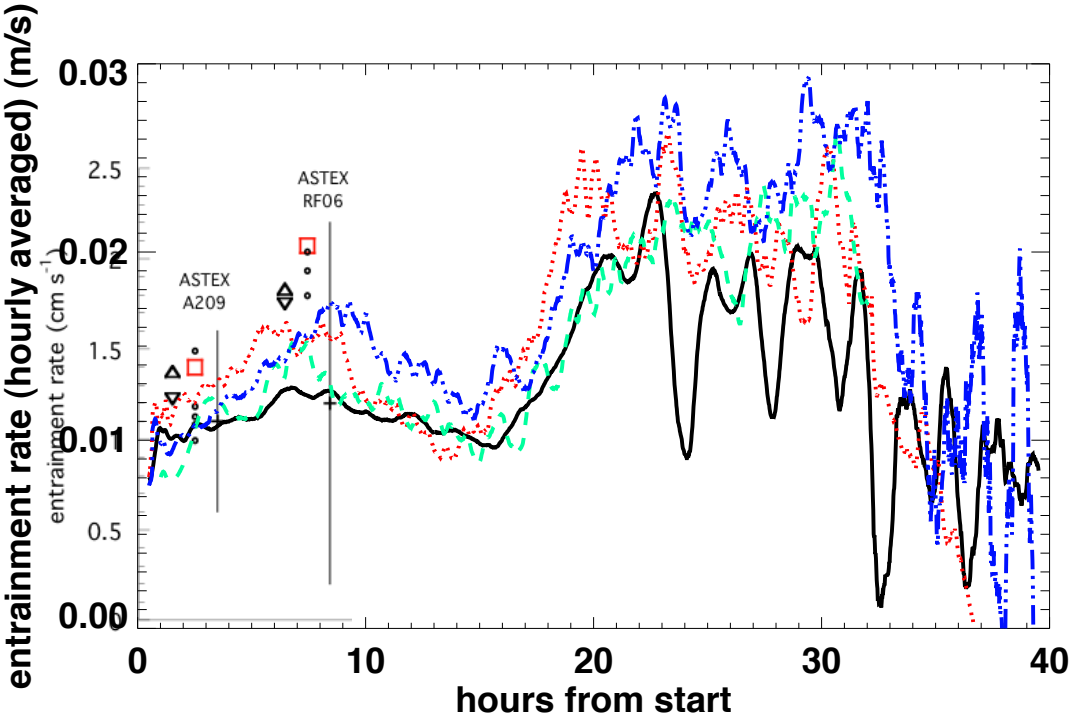


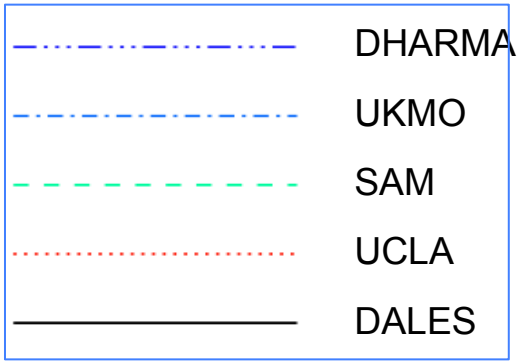


Model-dependent

More heavy and intermittent precipitation on a larger domain in DALES

Entrainment

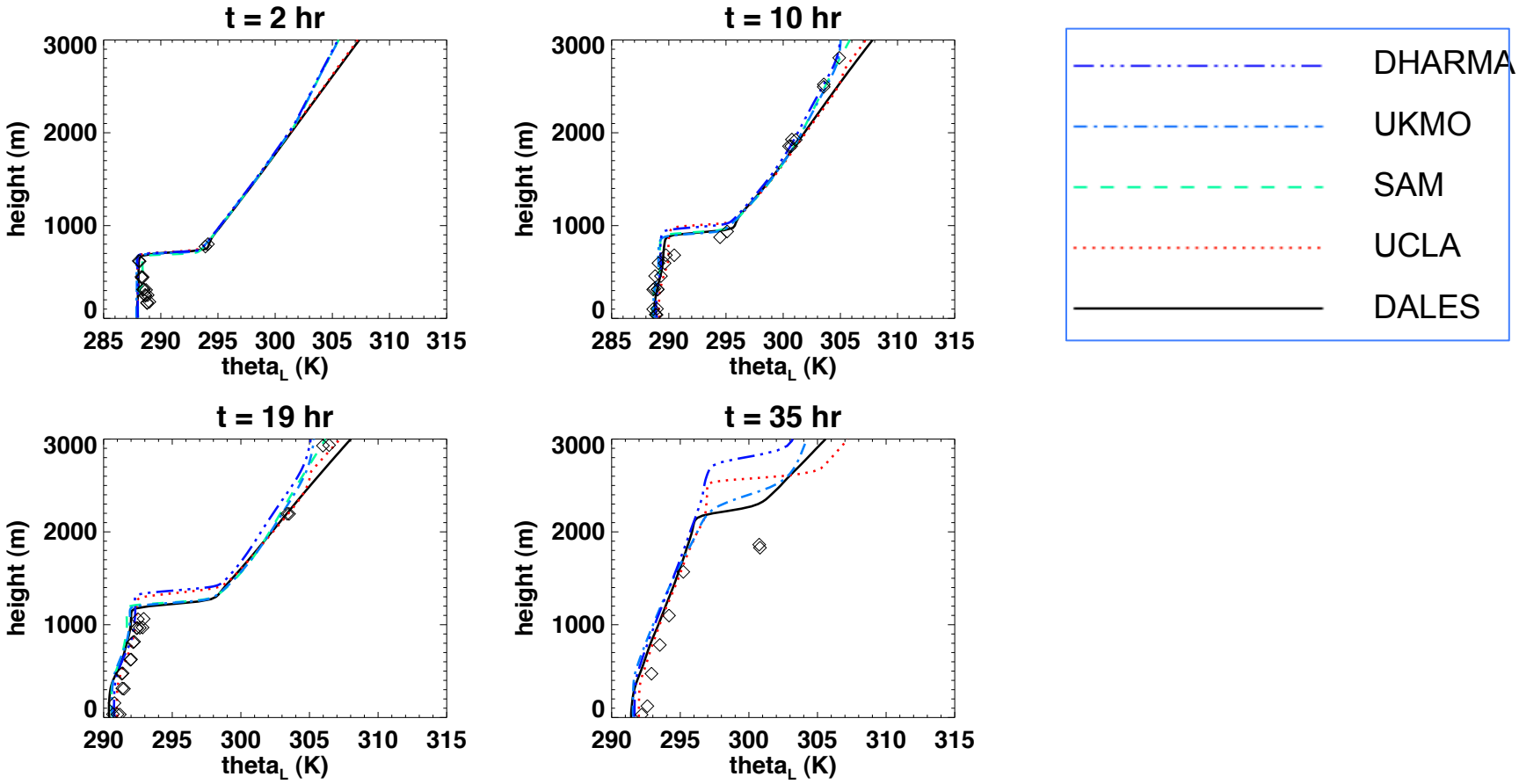




Entrainment rate doubles during the second night

Entrainment rate smaller than during previous ASTEX intercomparison case due to higher vertical resolution and inclusion of cloud droplet sedimentation (leading to reduced cloud top evaporative/radiative cooling).

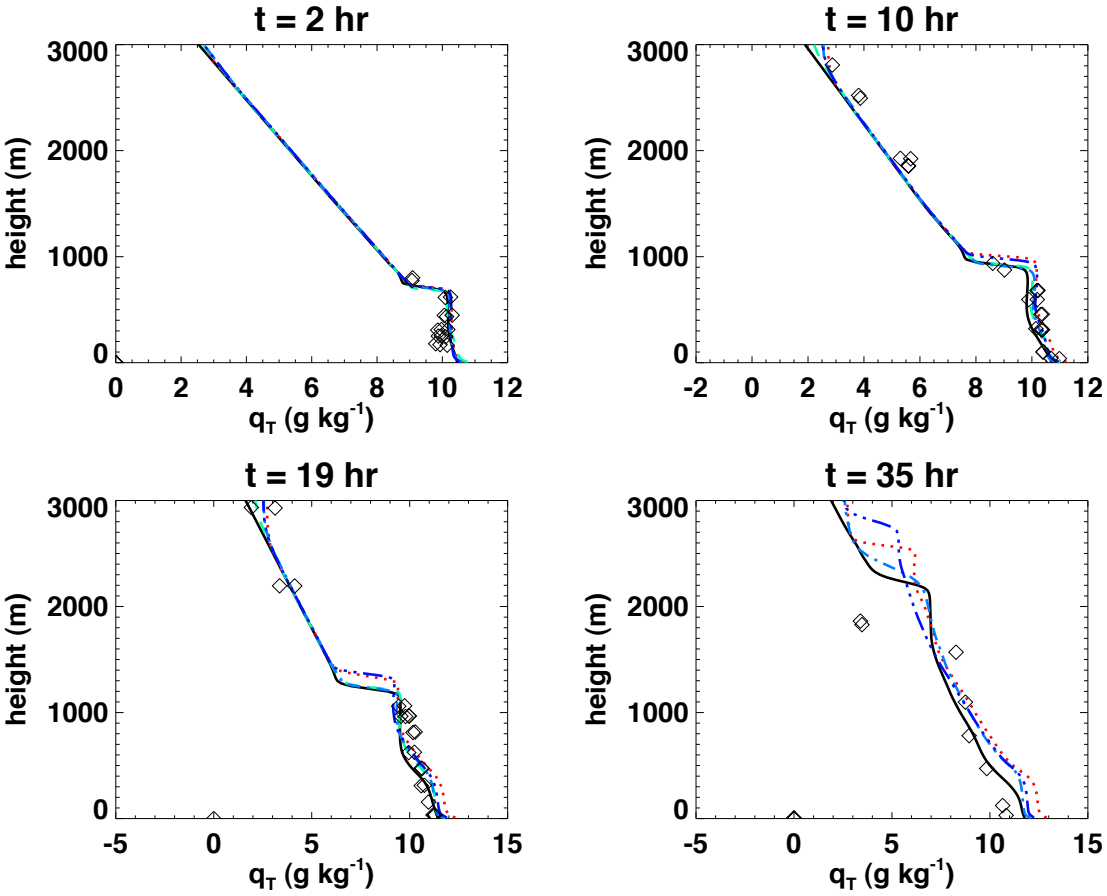
Liquid water potential temperature profiles

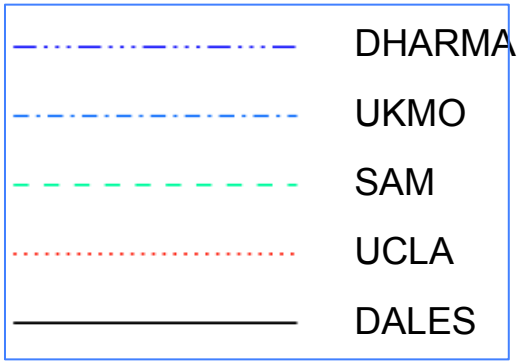


Slight differences in the upper part of domain:

- DALES & UCLA used ASTEX A209 specs with constant lapse rate

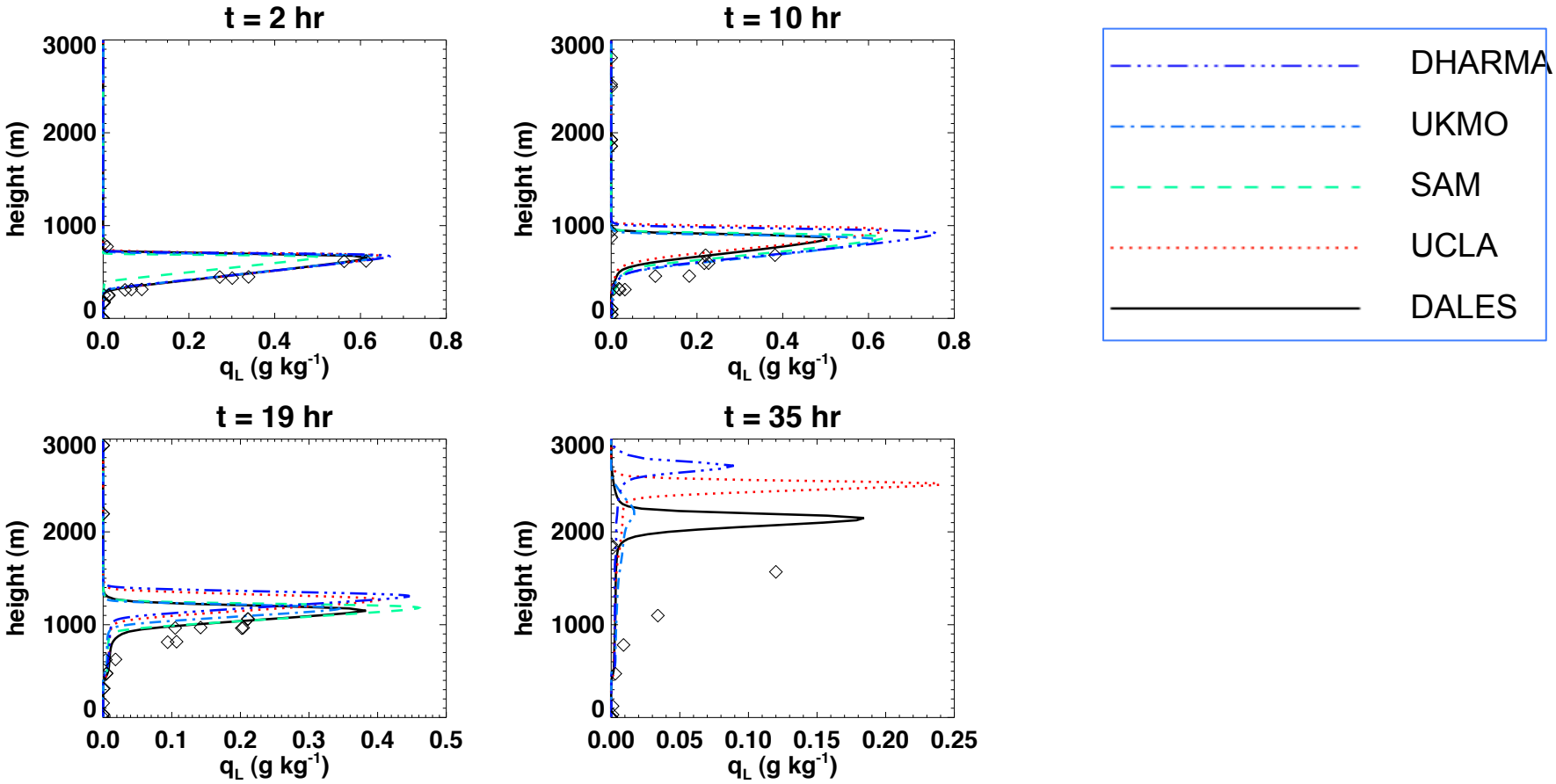
Total water content profiles





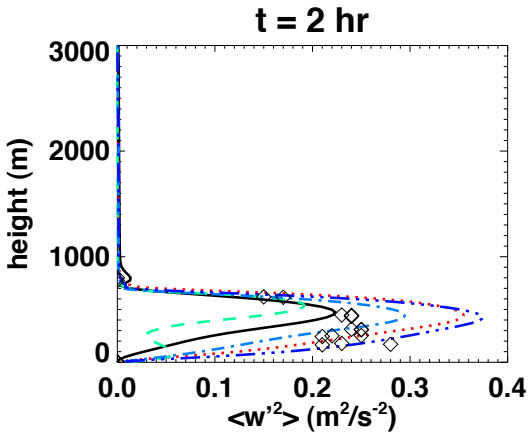
Mean state during first part of ASTEX Lagrangian is well represented

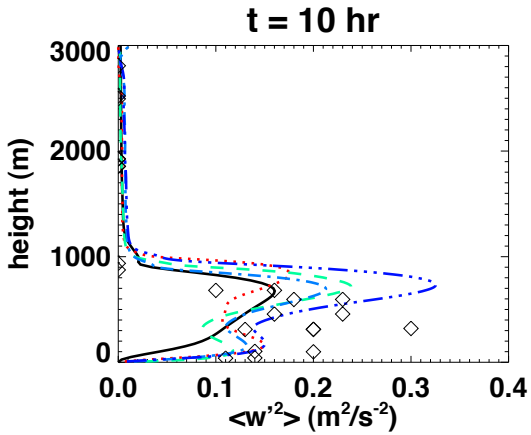
Liquid water content profiles

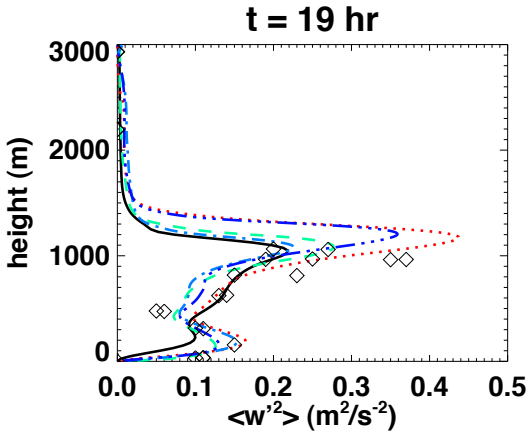


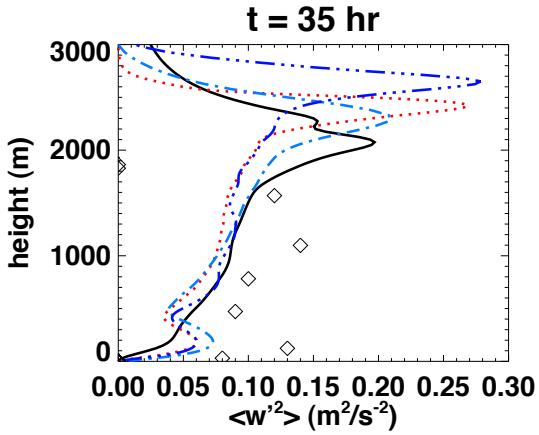
last part of simulation: wrong cloud height

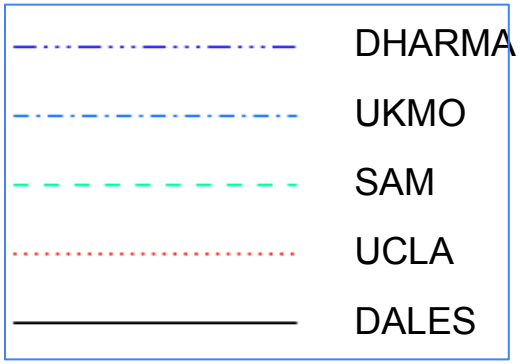
Vertical wind velocity variance









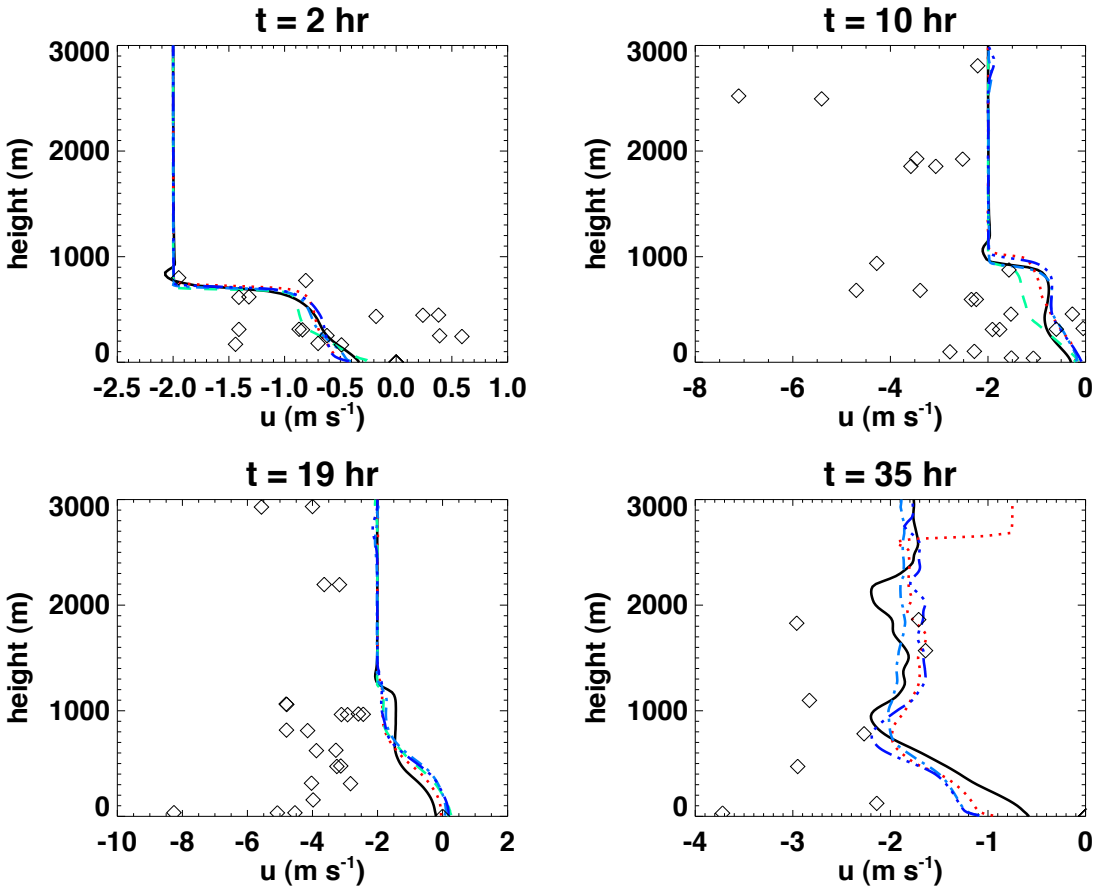


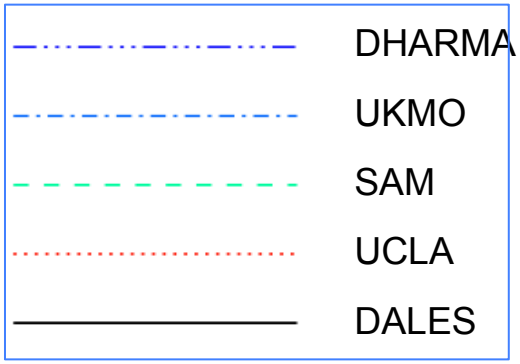
Conclusions

- Two new GCSS Sc-Cu single-column cases are attractive tests of NCEP and NCAR SCMs.
- LES agree well and are fairly consistent with observations on many aspects of these cases. They show rapid decoupling and later cloud breakup, and are a particularly useful guide to the vertical profiles of liquid water, cloud fraction and turbulent forcing/intensity.
- Sungsu will show NCAR SCM results for the Sandu case; Jennifer will be working toward implementing this case in the NCEP SCM.


Atmospheric Sciences
University of Washington

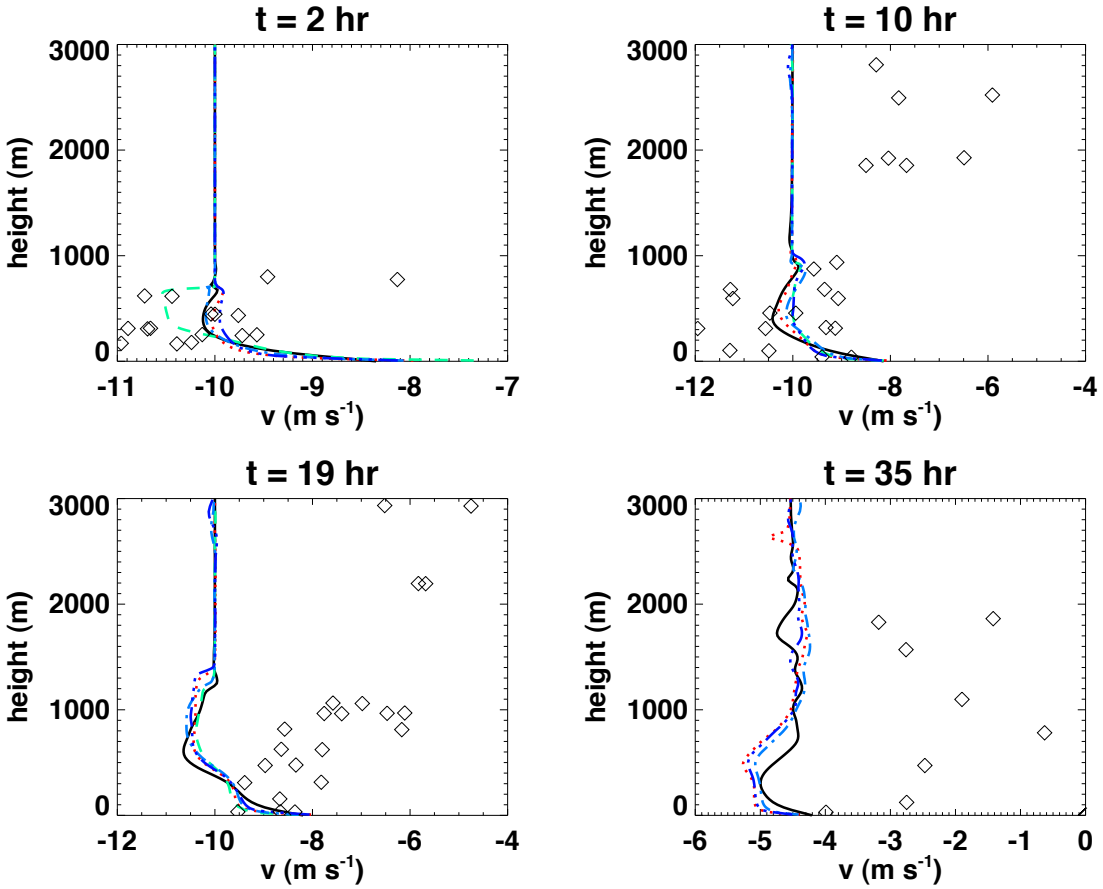
East-west wind component

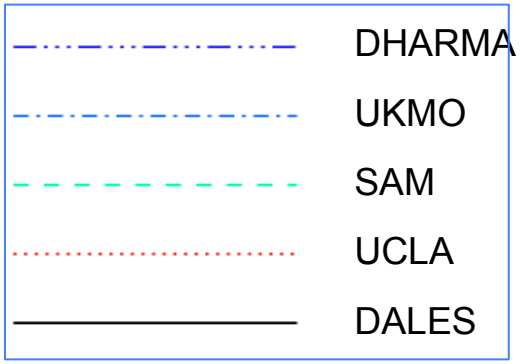




Change in geostrophic forcing well implemented

North-south wind component





Do we need a larger weakening of the geostrophic forcing?